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CHEMISTRY.—*The nitrogen problem in relation to the war.*[1] ARTHUR A. NOYES, Massachusetts Institute of Technology; Chairman of the Committee on Nitrate Investigations, National Research Council. (Communicated by L. J. Briggs.)

The subject with which I am to deal is so vast that it is impracticable to present more than a brief survey of it. I shall not attempt to go into technical details, but shall rather attempt to give you a general view of the situation, and a brief description of the various methods we have for meeting the demand for nitrogen compounds and of the principles which are involved in those methods.

You all realize the vital importance of an adequate supply of nitrogen compounds, particularly of nitric acid and ammonia, in ensuring our success in this war. From nitric acid are made all the important explosives such as smokeless powder, picric acid, ordinary black powder, dynamite, trinitrotoluol, and ammonium nitrate. This last has recently come into the greatest prominence as one of the most important and valuable of our explosives. In fact, it is reported that the Minister of Munitions of England has said that this war must be won with ammonium nitrate, as no other explosive can be produced in quantity adequate to meet the enormous demands of the Allied armies in

[1] Report of a lecture given before a joint meeting of the Washington Academy of Sciences and the Chemical Society of Washington on May 15, 1918.

Europe. This development of the use of ammonium nitrate has brought about a heavy demand for ammonia. In the early stages of the war it was anticipated that what we must look out for was an adequate supply of nitric acid, but at the present time we are no less interested in a sufficient supply of ammonia.

Let me briefly recall to you what are our sources of these two nitrogen compounds.

Our first source is Chile saltpeter, or sodium nitrate, which is found in a natural state in the dry regions of Chile, and which, until recently, furnished the total supply of nitric acid of the world. We depend for our own nitric acid supply upon the imports of Chile saltpeter into this country, which is a rather precarious source. In the first place, we are dependent on adequate shipping, and ships are scarce. In the second place, there has always been danger that enemy machinations, through interfering with production, destroying the plants, or blowing up the oil supply used for fuel, would reduce the production, or that our supply might be cut off entirely, by the establishment of a submarine base on the Pacific Coast. All of these possibilities make it unsafe to rely for our nitric acid supply on Chile saltpeter alone. But, even if none of these results actually came about, it would still be impracticable to get the huge amount of nitric acid that is going to be needed for the American Army through imports of Chile saltpeter.

Our second source is the ammonia from the by-product gas and coke ovens—the ovens, that is to say, in which coal is heated to produce gas or coke. We have, as I shall describe later, a well-developed process for the conversion of ammonia into nitric acid, so that if we get, from any source, an adequate supply of ammonia, we can convert in into nitric acid. I shall not enter at any length into the production of ammonia from gas and coke ovens. I will only recall to you briefly that for a long time, until within say ten years, this country was producing most of its coke in the so-called "beehive" oven, which is simply a hemispherical kiln. The coal is charged into the oven and set on fire, and the products of the combustion are allowed to pass into the air, so that the ammonia and valuable hydrocarbons that might have been

obtained are lost. During the last decade, and especially during the last few years, there has been a very rapid introduction of the so-called "by-product" ovens, in which the coal is heated in closed retorts and the gases are passed through condensers and scrubbers by which the hydrocarbons and the ammonia are recovered. It was alleged by some of those representing the by-product industries that this supply of ammonia would alone suffice to meet the military needs of the Government; but the result has proved that it is utterly inadequate. Even if we produced all of our coke in by-product ovens, the supply would be far from sufficient. Of course, the Government is interested in extending the introduction of by-product ovens as rapidly as possible; but the by-product industry is tied up with the steel industry. It is mainly in the metallurgy of steel that coke finds its use, and we can produce ammonia only in proportion as there is a demand for coke. It is true that in Germany, where in the early stages of the war the need for hydrocarbons was very acute, coal was coked extensively just for its ammonia and hydrocarbons, and great quantities of coke were piled up, to be used after the war. Our Government has not yet felt that our needs warrant such extreme action as this, as the value tied up in the coke is large compared to the value of the by-products, and the difficulties of securing deliveries are serious.

Our third source of these nitrogen compounds is atmospheric nitrogen. During the last fifteen years there have been developed a number of chemical processes by which the nitrogen of the air is "fixed," as we say, whereby ammonia, nitric acid, or sodium cyanide are produced. I wish particularly to speak of the four most important processes which have been operated on a commercial scale. These are the cyanamide process, the cyanide process, the arc process, and the synthetic process.

Let me briefly describe to you the principles involved in these different chemical processes. I shall endeavor to show you what materials are needed and how far power enters as a factor.

1. In the *cyanamide process* we start with lime and powdered coke. The first chemical reaction that takes place results in the formation of calcium carbide, as follows:

$$CaO + 3C = CaC_2 + CO.$$

This is the substance which is used so extensively in the manufacture of acetylene for oxy-acetylene welding. The carbon monoxide escapes as a gas. This first step in the cyanamide process is carried out in huge electric furnaces. The charge of lime and coke in small lumps is fed down through the furnace in the center of which stands a large carbon electrode. The walls of the furnace form the other electrode. The mixture is heated to a very high temperature, and the melted carbide is tapped off at the bottom from time to time and allowed to solidify.

The carbide is then crushed and subjected to the nitrifying process. Namely, it is packed into large basket-shaped containers 3 to 6 feet high and 2 to 3 feet in diameter, which are enclosed in an iron vessel supplied with nitrogen. The basket has holes through the sides, and down the center runs a resistance wire. The reaction is started electrically by heat produced by passing a current through the wire. The reaction which takes place is as follows:

$$CaC_2 + N_2 = CaCN_2 + C.$$

This gives us a product properly called "calcium cyanamide" which contains some unchanged carbide (about 3 per cent), and some lime and carbon.

The cyanamide process was the only one of the fixation processes which was being operated on any considerable scale in this country when we entered the war, and which is being so operated now. There is a plant operated by the American Cyanamid Company at Niagara Falls, Canada, which has been producing something like 20,000 tons of cyanamide a year. The product has been used to a limited extent in agriculture, but unfortunately the large amount of lime which it contains prevents it from being so used in unlimited quantities.

For the production of ammonia the cyanamide has to be treated with steam, whereby the following reaction takes place:

$$CaCN_2 + 3H_2O = CaCO_3 + 2NH_3.$$

This process is carried out in huge autoclaves about 20 or 30 feet high and 4 to 6 feet in diameter. The powdered cyanamide is fed into an alkaline solution and then steam is blown in; the

mass is heated, the reaction begins and becomes violent, and the ammonia is allowed to collect up to a pressure of 12 to 15 atmospheres, when it is blown off. Then, after the reaction has spent itself, the residue is again charged with steam so as to get a complete removal of ammonia. When carried out properly, it is practicable to get substantially all of the original nitrogen in the form of ammonia. This gives ammonia free from organic matter, except that it contains some acetylene, coming from the calcium carbide present.

2. I speak next of the *cyanide process*, in which the reaction that takes place is, in its net result, as follows:

$$Na_2CO_3 + 4C + N_2 = 2NaCN + 3CO.$$

A mixture of soda-ash with finely powdered coke and iron is heated at about 1000°C. in nitrogen gas. There is a considerable conversion of the sodium carbonate into sodium cyanide, with evolution of carbon monoxide. The iron acts simply as a catalytic agent. This operation is carried out in a number of different ways. In one of the forms of furnace, so-called "briquets," which are really pencils made by moistening the mixture and squirting it through a die, are fed down through a long tube 8 or 10 feet high, which is heated on the outside by flue gases from the combustion of coal. The heating gases pass around the outside of the tube. The charge feeds slowly down through the heated zone and is drawn out from time to time by a special device at the bottom..

As in the case of cyanamide, so in this case also, to get ammonia we have to treat the product with steam. If we treat it at a low temperature the cyanide gives ammonia and sodium formate:

$$NaCN + 2H_2O = HCOONa + NH_3.$$

When the formate is heated it breaks up, yielding sodium carbonate:

$$2HCOONa = Na_2CO_3 + CO + H_2.$$

Thus the sodium carbonate used in the process is regenerated. Really, all that is consumed is the carbon, and the nitrogen taken from the air.

The nitrogen used in both of the processes just described is obtained ordinarily from liquid air by one of the familiar liquefaction and distillation processes.

It will be noted that the cyanide process accomplishes in a single operation a result which requires two operations in the cyanamide process. By using soda instead of lime, we combine the two steps (conversion of lime to carbide and of carbide to cyanamide) into one. The final steaming is the same in both processes.

3. The *synthetic process* is an extremely simple one chemically, involving the following reaction:

$$N_2 + 3H_2 = 2NH_3.$$

There is a rather interesting history connected with this. The proportion of ammonia which forms from the elements (hydrogen and nitrogen) at atmospheric pressure at any temperature where the rate is rapid enough so that it will form within a reasonable time is extremely small. The proportions (by volume) of ammonia at various temperatures and pressures that are present when a mixture of three volumes of hydrogen and one of nitrogen reaches equilibrium are shown in the table:

	1 ATM.	100 ATM.	200 ATM.
degrees	*per cent*	*per cent*	*per cent*
500	0.13	10.7	18.1
600	0.05	4.5	8.3
700	0.02	2.1	4.1

Thus at 500° we find, from the laboratory investigations that have been made on the equilibrium of this reaction, that there is only 0.13 per cent of the nitrogen converted into ammonia when the mixed gases are at atmospheric pressure, whereas at 200 atmospheres there is 18.1 per cent. As the temperature rises the result is much less favorable. At 600° we get only 0.05 per cent, and at 700° 0.02 per cent, at atmospheric pressure. These unfavorable equilibrium conditions of the reaction, and the known fact that its rate is very slight until the temperature gets high, led to the belief that there was no hope of the development of

this reaction into a technical process. However, a German chemist, Haber, demonstrated, by working at high pressures and at the same time at the low temperatures made possible by the discovery of a good catalyst, that this reaction can be carried out on a commercial scale, and this is in fact being done very extensively in Germany.

4. Finally, we have the *arc process*, which, like the synthetic process, involves an extremely simple chemical reaction:

$$N_2 + O_2 = 2NO.$$

At a very high temperature nitrogen and oxygen unite to form nitric oxide. In this case the effect of temperature on the equilibrium is exactly the opposite of its effect on the ammonia equilibrium. The higher the temperature, the more nitric oxide is obtained; but there is very little until the temperature becomes very high. At 1600°, 0.4 per cent (by volume) of a mixture of equal parts nitrogen and oxygen is converted into nitric oxide; at 1900°, 1.0 per cent; and at 2400°, 2.2 per cent. It is clear, then, that we can get a considerable production of nitric oxide only by operating at a high temperature. But not only is it necessary to operate at a high temperature, but the gases must be cooled so quickly that in the process of cooling the reaction does not go back again. The gas must be cooled rapidly to such a temperature that the *rate* of decomposition of nitric oxide into oxygen and nitrogen is made very small. The only really practical way in which this can now be carried out is by using an electric arc. An arc produces locally an extremely high temperature, and the gas can be drawn rapidly away from the arc and quickly cooled.

Before describing the ways in which this reaction is carried out commercially, I shall first call attention to the remaining reactions which are involved in the production of nitric acid by the arc process. The nitric oxide, when the gas cools to below 150°, combines with oxygen to form nitrogen peroxide:

$$2NO + O_2 = 2NO_2.$$

This reaction does not take place instantly and time must be allowed for its completion. The peroxide is then treated with

water, three molecules of it forming two molecules of nitric acid and regenerating one of NO. The first reaction has again to produce more NO_2 before the next step can take place, and the fact that these reactions must go on successively explains the great difficulty in absorbing these nitric vapors in the absorption towers. Towers 60 feet high and 16 feet in diameter, placed six or eight in a series, are necessary in order to get 88 to 90 per cent absorption of the nitric vapors. As it does not pay to get the last 10 per cent in this way, this portion is absorbed either in caustic alkali, lime, or soda.

Two of the forms of furnace used may be briefly described. The essence of them all is to form an arc which will have a very large surface so that the gas will be brought into contact with the high temperature and will then cool off very rapidly. Various devices have been used for spreading the arc. The Birkeland-Eyde process, which is the one most used in Norway, uses an electro-magnet. If a magnet is placed at right angles to the arc, the well-known deflection of the electrified particles or electrons passing from one electrode to the other is produced, and thus the arc is drawn out into a disk-shaped flame. Another process for spreading the arc is known as the "Pauling process," an Austrian process, for which a small installation has been erected in this country at Nitrolee, South Carolina. The electrodes are water-cooled metal pipes. The arc forms between them and a blast of air spreads out the arc into the wider portion between the electrodes.

The arc process, when carried out in the manner described, consumes a very large quantity of electric power, and it is interesting to know where that power goes, because in this direction lies the main possibility of substantially improving the process. Of the electric power that is put into the arc only very little (3 or 4 per cent) is consumed in causing the union of nitrogen and oxygen to form nitric oxide. The rest of it is used merely for heating the entering gases from a comparatively low temperature up to the temperature of the arc. Only by devising an adequate preheating system, by which the outgoing gases heat to a fairly high temperature the incoming air, can we hope to increase very greatly the efficiency of the arc process.

Before reviewing the economic status of these different processes and their relation to our needs in the war, I wish to call your attention to one other chemical process, namely, the conversion of ammonia into nitric acid. If we are going to fix nitrogen as ammonia by either of the first three processes, we must convert it into nitric acid, and this is done by the following very simple chemical reaction with the aid of platinum gauze as catalyst:

$$4NH_3 + 5O_2 = 4NO + 6H_2O.$$

Ostwald, some twenty-five years ago, discovered that, when a mixture of air and ammonia is passed over platinum and certain other catalyzers, there is an oxidation of the ammonia in large measure to nitric oxide, which, when the gases are cooled and brought into contact with oxygen and water, goes through the two reactions that have already been described, and nitric acid is produced. This process has been perfected so that it is now a very valuable means for getting nitric acid from ammonia.

Let me now review the situation as to the development of these processes. The cyanamide process uses materials that are nearly universally available: limestone, coke, and nitrogen from the air. The limestone must be of good quality and free from magnesia to work satisfactorily, but there are abundant deposits all over the world of suitable limestone. It uses a moderate quantity of power; this is used especially in the first stage of the process, in the production of the calcium carbide. So, as a result of these conditions—the small amount of power and the availability of the materials—this process has been installed all over the world—in all the countries of Europe, in Japan, and at Niagara Falls, Canada. It is understood that since the beginning of the war the Germans have greatly extended their cyanamide plants, although they have probably been using the product mainly for fertilizer purposes rather than for the manufacture of explosives. At the present time, this is the only process on this continent which has been developed commercially on any considerable scale.

The synthetic process, which had been pretty well developed in Germany before the war, and which has undoubtedly been

much improved since, had fortunately been worked upon in this country by the General Chemical Company, and shortly after this country declared war, the company offered to the Government the use of its synthetic process for the production of ammonia. The company stated that they had so far perfected the process—well beyond the point which the Germans had reached before the European war—that they were able to operate at a temperature of about 500° and at a pressure not exceeding 100 atmospheres. The Germans, before the war, were operating at nearer 200 atmospheres and at a considerably higher temperature; and, as we have seen, higher pressures and higher temperatures both add to the difficulties of the process. The Government accepted the offer of the General Chemical Company, and as a result of it a plant is being built to operate this process at Sheffield, Alabama, which will have an output of about 20,000 tons of ammonium nitrate per year. The ammonia produced will be put through the oxidation reaction, converting it into nitric acid, and combined with more ammonia, because ammonium nitrate is the one thing which is needed in very large quantities at the present time.

The arc process would seem especially suitable for the production of nitric acid, as it is as simple as it can be chemically. The installation is somewhat expensive, but the really serious objection to it, particularly under American conditions, is the very large amount of power that is required. While the cyanamide process uses 2.2 horsepower-years per ton of nitrogen, the arc process uses nearer 10 horsepower-years. It can be economical, therefore, only where very cheap power is available. In Norway, where power costs about four dollars per horsepower-year, this arc process is being carried out on a very large scale, and the nitric acid is being sold partly to Germany, but mainly to the Allies.[2] In this country not only would the cost be very great

[2] The export of nitrates to Germany is now limited to 8,000 tons of calcium nitrate per year, while it is estimated that 112,000 tons (metric) per year will be available for export to the United States and Allies. (Agreement signed April 30, 1918, by representatives of the Norwegian Government and the War Trade Board, in effect May 10, 1918.)

because of the large power requirement, but power is not available that we can afford to devote to the process. There is a great scarcity of power in the eastern sections of the country even for the very necessary industries, and while there may be certain cheap powers on the Pacific coast, we have no ammonia there, as coke is not being produced; and we cannot therefore carry out the arc process in the Far West because we would not be able to ship the product in solid form. The arc process in its present form, therefore, does not look promising for use in this emergency; but if it could be perfected by a 50 per cent reduction in the power requirement, it would at once become an extremely valuable process. The arc process, I may add, is available in this country, all details being well known, so that if it were not for this power difficulty it could easily be installed.

There is also developing in this country, as a result of the investigations of Prof. J. E. Bucher, of Brown University, the cyanide process, which I have already described. The chemical reaction involved in it was well known, and the use of iron as a catalyzer had also been discovered; but the first attempt to put the process on a commercial basis was made by the Nitrogen Products Company, which has built a small cyanide plant near the Mathieson Alkali Works, at Saltville, Virginia, where nitrogen is available from the ammonia-soda process. The Government is also building a plant to operate this process under the rights which the Company has given to it. The Bureau of Mines is constructing this plant, which will produce 15 tons of sodium cyanide per day. Sodium cyanide itself is important; in fact, it is so valuable that it will not pay to convert it into ammonia until the market for cyanide has been satisfied; and it is also of some use in poison-gas work. Still, the use of cyanide is limited in gas warfare, and the demand for this purpose is not great.

Another company, the Air Reduction Company, has also worked out a cyanide process on a similar principle, and is prepared to make cyanide on a commercial scale.

Although this process has been put on a semi-industrial basis for the production of cyanide, the next step in it—the steaming of the cyanide for the production of ammonia—is still in the experi-

mental stage. There is no doubt that ammonia can be liberated almost quantitatively by proper steaming, and it is only a question of time when it can be worked on a commercial basis. The Government has no plant for the production of ammonia from cyanide, but it has installed a small plant in Rhode Island for the experimental production of ammonia, in cooperation with the Nitrogen Products Company.

One rather interesting question connected with the cyanide process is whether it will be best to convert the sodium formate, which results from the first reaction of steam on sodium cyanide, into formic acid in order to meet the serious shortage of acetic acid for airplane dope and other purposes; or whether it will be better to regenerate the sodium carbonate and use it over again in the process.

The Government, as I have said, is building a synthetic process plant with a capacity of 20,000 tons of ammonium nitrate a year at Sheffield, Alabama (U. S. Nitrate Plant No. 1). It is also building a cyanamide process plant with a capacity of 110,000 tons of ammonium nitrate at Muscle Shoals, Alabama (U. S. Nitrate Plant No. 2). And a third plant has been authorized for the production of another 110,000 tons of ammonium nitrate per year. It is to be located in Ohio, half of it at Toledo and half at Elizabethtown. It is hoped that the synthetic process in the first mentioned plant will be under way in the course of two or three months and that it may then be assured of success, so that the Government will be able to extend the synthetic plants. It is possible, also, that the cyanide process and the arc process may be developed so that they can be utilized.

Regarding the relative economies of the different processes, it is difficult to say anything very definite. It is clear, however, that the arc process in its present inefficient form is excluded, with power at the high cost that it has when it must be produced from coal. The arc process might be operated in competition with the other processes if power could be obtained at, say, $10 or $12 per horsepower-year. The cyanamide process has the advantage that it can be installed in many places in this country and that it requires little power. The cyanide process has a

similar advantage in that it, also, requires materials which are readily obtainable—soda ash, carbon, and the nitrogen of the air—and requires no electric power. While we have no very definite information as yet as to the relative costs of producing ammonia by the cyanamide and the synthetic processes, the estimates of those who have developed the latter and the reports that have come from Germany have indicated that the cost of production by the synthetic process in normal times will be very considerably less than that by the cyanamide process. It is true that the synthetic process involves high pressures requiring special machinery, but the other elements in it are more favorable.

The hydrogen that is required in the synthetic process is one of its large elements of cost. It is therefore important to get a cheap method for the production of hydrogen. The general method which has been adopted in Germany is to reduce water with coke, that is, to produce a mixture of hydrogen and carbon monoxide by the action of steam on coke and then to remove the carbon monoxide. This may be done by mixing the gas with steam and passing the mixture through suitable catalyzers, whereby carbon dioxide and hydrogen are formed:

$$CO + H_2O = CO_2 + H_2.$$

The carbon dioxide can then be absorbed out by scrubbing with water under pressure. This is a promising cheap way of getting hydrogen for use in the synthetic process.

Finally, I would say that the nitrogen problem is by no means a simple one, even at present. In order to supply our armies with the necessary amount of explosives, we shall need to use all our resources; (1) to continue and expand our imports on Chile saltpeter; (2) to introduce as rapidly as possible by-product coke-ovens; and (3) to develop at once new fixation processes. The last is our most vital chemical problem. The development of fixation processes is being largely done by the Government through the Nitrate Division of the Ordnance Department. The Bureau of Mines has also been carrying on extended investigations in this direction; thus the oxidation process where the mixed gases are passed over red-hot platinum gauze has been

brought to a very high stage of perfection by this Bureau, yields of from 92 to 95 per cent conversion of the ammonia being attained. The process of absorption of the nitric vapors has been much simplified by the work of the Nitrate Division. And all along the line we may hope, as a result of the war, that during the next year or two there will be a very marked development of our processes of nitrogen fixation.

I hope that this brief outline may have served to give you a general survey of the situation with reference to our supply of nitrogen compounds and the means available for meeting the demand for them in this country.

ORNITHOLOGY.—*Diagnosis of a new genus of Timaliidae.* HARRY C. OBERHOLSER, Bureau of Biological Survey.

The genus *Zosterornis* Grant, a group of *Timaliidae* allied to *Mixornis*, at present comprises seven species, all peculiar to the Philippine Islands. It was originally described[1] by Mr. Ogilvie Grant for the reception of a new bird, *Zosterornis whiteheadi* Grant, discovered by Mr. John Whitehead in the island of Luzon. Since then three more species have been described, and three others originally referred to the genus *Mixornis* have been transferred to the same group. All of these, however, excepting the type of *Zosterornis* and possibly *Zosterornis striatus* Grant, which latter we have not seen, are not congeneric, and it is therefore necessary to provide for them a new generic name.

Sterrhoptilus,[2] gen. nov.

Chars. gen.—Similar to *Zosterornis* Hodgson, but tarsus relatively, as well as actually, much shorter, being less than one and one-half times the length of bill, and only three-tenths or less of the length of the wing; middle toe without claw decidedly shorter than exposed culmen, instead of about equal; tail not almost square, but rounded, even somewhat graduated; first primary (counting from the outermost) about half the length of the second, not decidedly more, as in *Zosterornis;* feathers of pileum narrowed, stiffened, and somewhat pointed, not broad and rounded at their ends as in *Zosterornis.*

Type.—*Mixornis capitalis* Tweeddale.

[1] *Zosterornis* Grant, Bull. Brit. Ornith. Club **3**: No. 19, June 30, 1894, p. l. [50]. (type by original designation and monotypy, *Zosterornis whiteheadi*, sp. nov.).

[2] Στερῥός, *rigidu* , πτίλον, *penna.*

Remarks.—One of the nearest allies of this genus is *Mixornis* Hodgson, of which the type is *Motacilla rubricapilla* Tickell, but *Sterrhoptilus* differs from this group in the very different shape of the nostrils, which are not rounded as in *Mixornis*, but narrow, almost slit-like, and very strongly aperculate; the rictal bristles are much shorter and weaker; the bill is narrower and more slender; the first primary narrower and about half the length of the second; and the middle toe without claw is shorter than the exposed culmen. All the species here referred to *Sterrhoptilus* have the upper surface more or less streaked, not plain as in *Zosterornis whiteheadi;* and furthermore there is no white eye-ring in any of them. This new genus is of interest as another instance of the wonderful variety of structure among the babblers; and, furthermore, it adds another endemic genus to the avifauna of the Philippine Islands. The species referable to this group are as follows:

Sterrhoptilus capitalis (Tweeddale).
Sterrhoptilus plateni (Blasius).
Sterrhoptilus dennistouni (Grant).
Sterrhoptilus nigrocapitatus (Steere).
Sterrhoptilus pygmaeus (Grant).

TECHNOLOGY.—*Variance of measuring instruments and its relation to accuracy and sensitivity.*[1] FREDERICK J. SCHLINK, Bureau of Standards.

While the general concepts of accuracy and sensitiveness in connection with measuring instruments are well known, certain phases of the meanings of those two terms have not been clearly differentiated, and the factor of variance which bears an important relation to the two just mentioned has not hitherto been given extended discussion or made susceptible of definite numerical expression.

Accuracy and inaccuracy defined. An instrument is accurate when its indications accord with the true values of the quantity being measured. Perfect instrumental accuracy, then, is only an

[1] A brief presentation, based on the complete paper now in press, and to appear as a Bureau of Standards Scientific Paper.

ideal, but we may define instrumental accuracy numerically in terms of the error or correction corresponding to various values of the quantity to be measured. The error arising from whatever source, observed in an indication of the instrument, divided by the true value of the measured quantity, may be termed the *inaccuracy* at a given reading, the negative term being justifiable on the basis of custom and ease of application. With this in mind, it is seen that *accuracy* may be expressed as the ratio of the value of the quantity being measured to the error of the instrumental indication at that value (this of course being the reciprocal of the quantity defined above). The ratio expressing instrumental accuracy, while not of value in the ordinary use of instruments, will be of service in rating the performance of an instrument.

Sensitivity defined and distinguished from immediacy of response. Any instrument showing a change of reading for any change, however great, in the quantity being measured may be said to be sensitive. This term again requires expression in numerical terms in order to be of value in studies of measuring instruments. Statements of sensitivity of instruments are often erroneously based upon that change in the value of the measured quantity producing the smallest perceptible response in the indication of the instrument. This method of expression is by no means a satisfactory one, since it disregards the factor of sluggishness or passiveness in instrument performance, a matter more fully discussed later—and moreover involves the error of personal judgment of the observer. The rating of sensitivity on the basis of the purely incidental dimension of some part, such as the length of a pointer or an arbitrarily graduated scale over which the pointer moves, is also unsatisfactory, since the pointer length or the graduation interval is subject to wide change within the discretion of the designer, making comparison of the sensitivity of different instruments unreliable and dependent upon factors of a purely accidental character. A better basis, in instruments having a rotating or oscillating indicator, would be the angular deflection of the indicator per unit change of the measured quantity—for example, in a balance, the angular deflection of the rest

position of the beam per unit addition of load to the load pan, the first expressed in radians, and the second in grams. Actual measurements of sensitivity will, of course, be restricted to small deflections so that variations in its value over the range of deflection are negligible.

The frictional resistance to turning or sliding within an instrument has an important bearing upon the concept of sensitiveness. The effect of frictional resistances is to retard or delay the motion of the indicating element for both increasing and decreasing values of the quantity being measured, and to prevent response of the instrument reading to certain small changes in the measured phenomenon. Its existence requires the modification of the ordinary concept of sensitivity since otherwise the determination of the sensitivity of an instrument would depend upon the absolute rather than the relative magnitudes of the quantities entering into the observation. During the period in which change of the measured quantity is proceeding without the occurrence of any motion of the indicator, owing to the effect of static friction, application of the ordinary definition of sensitivity would give a zero value for that quantity. It seems necessary, then, to separate the sluggishness factor from the insensitiveness factor and define sensitivity thus: Sensitivity in an instrument is the rate of change in the indication of such instrument with respect to change in the quantity being measured, it being necessarily assumed for the purposes of this definition that friction and lost motion in the mechanism have been eliminated or are negligible. (A similar postulate applies to the determination of the scale value in instruments graduated directly in the units of the quantity being measured.) We have thus distinguished between passiveness (or sluggishness) and instrumental insensitiveness, a distinction that so far as known to the writer, has not hitherto been set forth. The amount of the least alteration in the value of the measured quantity producing instrumental response, divided by the initial value of the measured quantity may be called the passivity of the instrument at that point.

Variance defined and illustrated. Passiveness, defined above, is a special case of the phenomenon of variance, which is defined

as the range, at any given value of the measured quantity, of variation in reading which may be exhibited by the instrument under repeated application of the same value of the quantity being measured, after a steady reading has been attained, the environment remaining unchanged. This quantity represents the range of uncertainty of the indications of the instrument. The specific variance may be defined as the ratio of the range, at any given value of the measured quantity, of variation in reading which may be exhibited by the instrument under repeated application of the same value of the quantity being measured, divided by the measured quantity itself, the same assumptions applying as above as to the attainment of a steady state of indication and as to the maintenance of unchanged environment. This factor has rarely been determined in tests of measuring instruments; ignoring it in their use, as is commonly done, may cause appreciable error, and it is therefore important that it be recognized or expressed.

In the case of the usual direct-reading instrument, the variance is disclosed in the displacement observed between the upward and downward branches of the hysteresis loop obtained by plotting instrument readings (or corrections or errors) against actual values of the measured quantity over a complete cycle of increasing and decreasing values. The amount of the variance will depend upon the previous history of the instrument and upon the immediately precedent cycles of movement which the instrument has undergone. The hysteresis curve obtained by plotting in the manner outlined is a valuable index to the operating characteristics of an instrument and leads to the detection of defects in design and workmanship discoverable with certainty in no other way. Figures 1 and 2 illustrate the effect described. In figure 1 it is to be noted particularly that the instrument contains no force-measuring elements of the elastic type, the scale in question being a pendulum-operated device, so that the loop shown is not the result of hysteresis of inelasticity. The sources of the hysteresis exhibited are all expressible as backlash or are closely analogous to it. The median line of the loop of figure 1 gives the characteristic error of the scale correctable by suitable

alterations of the weight of the pendulums and of the contour of the cams about which the load transmitting tapes wrap, while the width of the hysteresis loop gives a good index to the workmanship of bearings and connections.

Backlash an important cause of variance. In a measuring instrument the maintenance of constant or at least determinate

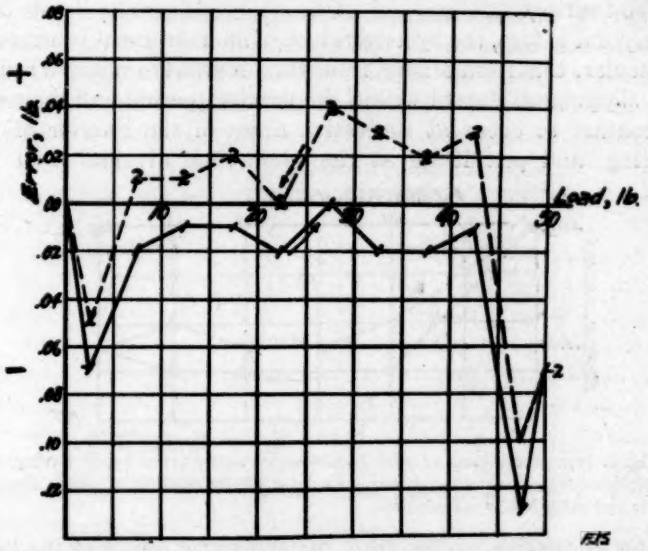

Fig. 1. Hysteresis loop of automatic weighing scale of the cam-pendulum type (comprising no elastic force-measuring elements). Note the manner in which the curve of decreasing readings reflects the aberrations of the curve of increasing readings, with a distinct tendency toward wider separation at the middle of the load range, so that the hysteresis loop would have a distinctly lenticular form, if the median line or mean error curve were rectilinear.

intervals between the parts of the mechanism is essential in the transfer of the forces or motions from the point of their reception to the point of registration or indication. Slack or backlash in the mechanism has the same effect as an equivalent advertent displacement of operating parts, backlash being used to imply looseness of fit resulting in play of the coacting parts. Actually, the action of backlash is not the simple one of producing a hystere-

sis loop of the rhomboidal form of which the two horizontal sides correspond to the geometrical clearance in the bearing. This type of hysteresis loop may be eliminated from consideration since instrument mechanisms almost invariably comprise an element to provide force-closure of the linkwork, so that the journals tend to remain in contact with the same general faces of the bearings.

In point of fact, the hysteresis loop of an instrument is normally lenticular, this form arising from the progressive relative rolling and slipping of journal within the bearing, permitting the point of contact to occur at successive zones of the interior of the bearing, and permitting at the same time divagation of the

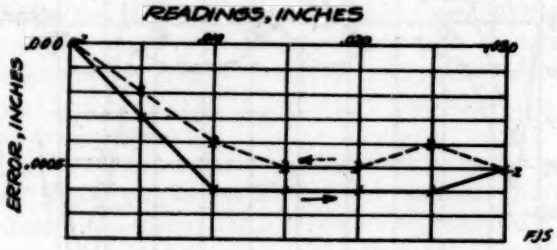

Fig. 2. Hysteresis loop of dial indicator of screw-train type, having high multiplication; an instrument much used for direct reading of small displacements and other linear magnitudes.

center of relative motion from the geometric center of the bearing. This action is suggested in figure 3. The effect of this action in producing variance arises in the modification of the instrument magnification or leverage ratio which it permits. In the case of instruments comprising spring force-resisting elements, a similar loop arising from inelastic actions of the spring will be combined in the calibration curve with that due to backlash.

When the calibration curve fails to form a completely closed loop due to incomplete reversion of the parts of the mechanism the residual deflection may be termed the *set*.

Clearance between engaging teeth of gearing introduces backlash effects of the same general nature as those outlined above.

In gear trains, moreover, there is especial likelihood of the occurrence of the rhomboidal type of hysteresis loop since actual discontinuities in the transference of motion from one part of the train to another will follow directly from any clearance at the pitch line.

Evaluation of irregular variance. In some instruments, especially those characterized by poor workmanship or ill repair, successive hysteresis loops may be far from concordant in their shape or magnitude on account of actual variations in the friction and journal displacements at any particular indication. In cases of this kind, the variance may be expressed or defined by

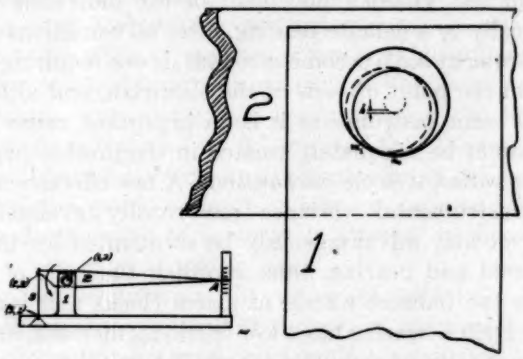

Fig. 3. Illustrating operation of instrumental backlash

plotting frequency curves of the readings or errors obtained for a given value (or for a series of definite values) of the same measured quantity repeatedly applied—one series of points being plotted for increasing readings terminating in the value under investigation, and another set for decreasing values terminating at the same point. Such a curve may exhibit, for example, probability of occurrence of any amount of variation from the mean instrumental reading. A succession of such frequency curves taken over various parts of the reading range will determine a surface enabling one to ascertain the probability of a given error at any point of the reading scale, but its principal utility will be in affording a criterion as to the comparative

performance with regard to variance, of instruments of diverse design or workmanship.

Far from being a relatively unimportant source of inaccuracy in measuring instruments, it can be shown that the hysteresis or variance type of error demands consideration in practically every type of instrument, while in some (such as pointer-and-dial types of displacement-indicators) the variance is a preponderant factor in design and actually sets the limit of sensitivity and accuracy practicably obtainable, so limiting the application or utility of the instrument.

The phenomenon of drift, which is a time effect characterized by more or less gradual movement of the indicating element asymptotically to a definite reading, after all conditions external to the instrument have become constant, is one requiring investigation from the point of view of the elastician, and although in the case of some instruments it is an important cause of variance, it cannot be adequately treated in the present paper.

Reducing variance in the mechanism. A few effective means of reducing instrumental variance are readily available. The conical pivot may advantageously be substituted for the cylindrical journal and bearing, thus affording the type of bearing familiar in the balance wheels of alarm clocks and low priced watches. Such a bearing has a low frictional moment, and maintains a practically invariable relation of bearing to journal but cannot, of course, support any considerable load. The use of flexible or ribbon-like connectors secured by simple clamps at their extremities, between members which are to be conjoined, instead of the more usual rigid pin-and-link connectors is ofttimes a very useful device and has the advantage of providing for correction of motion to obtain a linear scale of graduation, by the simple expedient of arranging that one or both ends of the tape shall wind upon a cam of suitable contour. This type of connector contributes very little indeed to the hysteresis of the complete mechanism, since practically the only source of irreversibility in such a tape is the hysteresis of inelasticity, which in absolute value is very small. Simplifications of mechanism are often possible to eliminate the number of links involved and

hence the number of bearings at which backlash effects can occur.

The action of vibration in reducing instrumental variance is found to accord well with the principles previously set down. Owing to the minimization in the static friction, occasioned by the vibration, on account of the momentary disengagement or separation of coacting bearings and journals, a considerable reduction of instrumental variance arising in mechanistic causes will normally take place,—thus the energy required to bring the parts to their theoretical equilibrium point is in a sense supplied from without the system.

Variance as a limiting factor in design and adjustment. In designing and constructing instruments, consideration should be given to the effect of variance errors in practically limiting the sensitivity obtainable by adjustment, as well as in determining the optimum interval between graduations or the smallness of the units of graduation. It is suggested that the mean interval of graduation of laboratory instruments should not be less than five times the mean variance, while for commercial or plant instruments the ratio of mean scale interval to mean variance may be of the order of two to one.

Inconsistencies between the values of sensitivity, variancy, and smallness of the units of graduation of instruments are common; tachometers, for example, are often graduated to a single mile per hour, while there may be a variation of reading at a given rotational speed of five miles per hour or more. Similarly weighing scales and balances often show variations of a full graduation or more. Likewise the sensitivity may easily be disadvantageously high, inducing erroneous estimates of the precision of results and requiring special care in the calibration and use of the instrument.

In particular cases in fact, a low inherent sensitivity may actually tend to reduce the absolute amount of the variance as in precision balances, where the advantages gained by the use of a low angular sensitivity and high magnification with the resulting quick period of oscillation, are well known.

The factors of maximum or mean inaccuracy (or accuracy), sensitivity, variancy, and specific set (the amount by which the

variance loop may fail of closure, divided by the range of the deflection cycle) may be referred to the total range of graduation instead of to particular values of the measured quantity under observation, as a convenient means of arriving at single significant numbers to be composed into a "figure of merit" for an instrument whose characteristics are being determined. It is most desirable to develop definite numerical means of comparison between different instruments or different types of instruments for the same purpose, and the methods just suggested will afford a satisfactory basis for attaining this end, just as the aeronautic engineer's choice of structural material for a given purpose may be based on a single "figure of merit" involving the unit weight, strength, and stiffness determined by laboratory tests.

ABSTRACTS

Authors of scientific papers are requested to see that abstracts, preferably prepared and signed by themselves, are forwarded promptly to the editors. The abstracts should conform in length and general style to those appearing in this issue.

GEODESY.—*Lambert projection tables for the United States.* OSCAR S. ADAMS. U. S. Coast and Geodetic Survey Spec. Pub. No. 52. Pp. 243, including 33 pp. of text. 1918.

This publication consists of general tables of coordinates for the United States, computed on the Lambert conformal conic projection, with two standard parallels. The coordinates are given in both meters and yards for the intersections of the parallels and meridians at every half degree in both latitude and longitude. Detail tables for local maps in both meters and yards are given in coordinates for the intersection of the parallels and meridians at intervals of 5 minutes in both latitude and longitude; and for two degrees out from a central meridian. The introductory text includes a mathematical development of the formulas of the projection, followed by a full description of the use of the tables in the construction of projections. Eleven diagrams serve to illustrate the manner in which the tables should be used in constructng a map of any section. As a whole, this publication contains the most complete set of tables of the Lambert projection ever issued for any region as extensive as that of the United States. For the construction of a general map of the United States the system is about the best that can be devised. O. S. A.

SPECTROSCOPY.—*The application of dicyanin to stellar spectroscopy.* P. W. MERRILL. Bur. Stand. Sci. Paper No. 318. Pp. 18. 1918.

This paper describes the use of commercial photographic plates sensitized with dicyanin in stellar spectroscopy. The first observations were carried out at the Harvard College Observatory using the 24-inch reflecting telescope and objective prism. Fraunhofer's A band (wave length 0.760 μ) and a considerable region of greater wave length were photographed in numerous stellar spectra. Several new absorption

flutings were discovered, the most striking beginning at 0.760 μ nearly coincident with A, and running toward the red. Circumstances indicated that this band might be due to titanium oxide, and experiments since made at the Bureau of Standards have shown a band in this position in the spectrum of the titanium arc. The general conclusions arrived at are as follows:

1. Many stellar spectra possess sufficient intensity in the region of wave length 0.80 μ to enable this portion of the spectrum to be photographed on plates sensitized with dicyanin.

2. In favorable instances stellar spectra can be well observed to wave length 0.85 μ.

3. The region of greater wave length than 0.70 μ contains features of importance, especially in the case of the later spectral types.

P. W. M.

METALLOGRAPHY.—*Typical cases of the deterioration of Muntz metal (60–40 brass) by selective corrosion.* H. S. RAWDON. Bur. Stand. Tech. Paper No. 103. 28 pp. December 15, 1917.

Brass of the type 60-copper and 40-zinc, which is used commercially in a variety of forms, e.g., wrought bolts, sheathing, condenser tubes, extruded forms, etc., often shows a kind of deterioration by which the metal changes its color to copper-red and becomes very weak and brittle although the shape and size apparently remain unchanged. This change of properties is due to a selective corrosion of the alloy, which has a duplex structure, when exposed to the action of some electrolyte, particularly sea-water. The present study includes bolts, boat sheathing, condenser tubes, and parts which were corroded while under stress.

The examination of the microstructure shows clearly the method of the attack, the zinc-rich constituent being electrolytically "leached out" leaving a skeleton of weak pulverulent copper. Later the second constituent may be attacked so that the whole specimen is converted into pulverulent "copper"—the sample becoming so weak that it can be broken into fragments in the fingers.

Conditions that appear to accelerate corrosive attack of this type are: the microstructural composition of the alloy, contact with strongly electronegative metals, the effect of certain adhering deposits of basic zinc chloride resulting from the corrosion, the thoroughness of the later than common. There was a roost of about 500 *Sturnus vulgaris*

annealing the sample has previously received, the temperature of the electrolyte, and the stresses to which the specimens are subjected during the corrosive attack.

H. S. R.

ORNITHOLOGY.—*Winter birds about Washington, D. C., 1916–1917.* W. L. McAtee, E. A. Preble, and Alexander Wetmore. Wilson Bull. **29**: 183–187. 1917.

A record winter list of 48 species for one day in the vicinity of Washington was obtained on December 30, 1916. A list of the species, together with the number of individuals of each seen is given in this paper. A list of 33 additional species, all observed during the winter of 1916–1917, is also added. This combined list of 81 species comprises about two-thirds of the known winter birds of the region, and represents the results of unusually favorable conditions, although the list includes very few species that are rare in the District of Columbia.

Harry C. Oberholser.

ORNITHOLOGY.—*An abnormal egg of* Fulica americana. Alexander Wetmore. Condor **19**: 65–66. 1917.

A female of *Fulica americana*, caught alive in the delta of Bear River, Utah, was found on the following morning to have laid an egg of strikingly abnormal coloration, very much darker than the usual eggs of this species. The cause of this abnormality is attributed to the continued excitement and fear of the bird at the time of its capture and the consequent reactions of the nervous system upon the organs of the oviduct.

Harry C. Oberholser.

ORNITHOLOGY.—*Washington region* [*June to September, 1917*], Harry C. Oberholser. Bird-Lore **19**: 277; 339–340. 1917.

The unusually late spring migration of birds about Washington, D. C., during 1917 extended well into June, and many migrants remained later than ever known before. Conspicuous among these were *Empidonax minimus*, June 2, *Dendroica castanea*, June 5, and *Oporornis philadelphia*, June 7. A few of the summer residents were also more than ordinarily numerous.

During August and September, 1917, about Washington, D. C., some migratory birds appeared earlier than usual. Most notable among those was *Marila affinis*, seen August 31, of which the earliest previous record was September 25. A number of other birds, however, remained here

vulgaris in the trees of the Mall, in the city of Washington, whither also 1000 to 5000 individuals of *Quiscalus quiscula quiscula* and for a few weeks several thousand purple martins, *Progne subis subis*, resorted.

H. C. O.

ORNITHOLOGY.—*Mutanda ornithologica. II.* HARRY C. OBERHOLSER. Proc. Biol. Soc. Wash. **30:** 125–126. 1917.

In this, the second, paper on the nomenclatural status of certain birds the following changes are indicated: The parrot commonly known as *Loriculus inducus* (Gmelin) must hereafter be called *Loriculus asiaticus*) (Latham); *Polytelis barrabandii* (Swainson) must be known as *Polytelis swainsonii* (Desmarest); *Triclaria cyanogastris* (Vieillot) must hereafter be called *Triclaria malachitacea* (Spix); *Pyrrhura bittata* (Shaw) is changed to *Pyrrhura frontalis* (Vieillot); *Nasiterna pygmea* (Quoi and Gaimard) is renamed *Micropsitta chloroxantha* Oberholser; and *Malacoptila torquata* (Wagler) is changed to *Malacoptila strata* (Spix).

H. C. O.

ORNITHOLOGY.—*Descriptions of two new birds from Haiti.* CHARLES W. RICHMOND. Smiths. Misc. Coll. **68:** No. 7, 1–3. 1917.

In this paper there are described two more of Dr. W. L. Abbott's remarkable ornithological discoveries on the island of Santo Domingo. The first and most interesting is a new *Nyctibus*, a genus of big goatsuckers not hitherto recorded from the island of Santo Domingo, and here described as *Nyctibus griseus abbotti*, after its discoverer, the well-known traveller and naturalist. The single specimen was obtained at Port de Pimente, northwestern Haiti. The other new bird is *Vireo crassirostris tortugae*, from Tortuga Island, off the northwestern coast of Haiti.

HARRY C. OBERHOLSER.

ORNITHOLOGY.—*The relationships of the fossil bird* (Palaeochenöides mioceanus). ALEXANDER WETMORE. Journ. Geol. **25:** 555–557. 1917.

The bird described by Dr. R. W. Shufeldt as *Palaeochenöides mioceanus*, from the distal end of a femur found in South Carolina, was considered by him to be of Anserine affinities. A reexamination of the specimen, however, now shows that it is unmistakably a member of the Steganopodes, and is apparently most closely allied to the Pelecanidae, though it may represent a distinct family. HARRY C. OBERHOLSER.

ORNITHOLOGY.—*On the fauna of Great Salt Lake.* ALEXANDER WETMORE. Amer. Nat. **50:** 753–755. 1917.

Contrary to common belief, the Southern Pacific cut-off on Great Salt Lake has not interfered with the free interchange of water or of aquatic animal life between the portions north and south of this causeway. Brine shrimp (*Artemia fertilis*) and three species of alkali flies of the genus *Ephydra* occur here in great numbers. Several species of water-birds, chiefly *Spagula clypeata, Marila affinis, Clangula clangula americana,* and *Nettion carolinense,* together with *Steganopus tricolor, Lobipes lobatus, Recurvirostra americana, Himantopus mexicanus,* and doubtless other allied species were feeding on these small animals and doubtless destroyed great numbers of both the shrimp and alkali flies.

HARRY C. OBERHOLSER.

ORNITHOLOGY.—*A new cuckoo from New Zealand.* ALEXANDER WETMORE. Proc. Biol. Soc. Wash. **30:** 1–2. 1917.

Representatives of *Urodynamis taitensis* (Sparrman) from New Zealand differ from those of the same species from Polynesia. Since the type locality of *Urodynamis taitensis* has been fixed as Tahiti, the New Zealand bird is here named *Urodynamis taitensis pheletes.*

HARRY C. OBERHOLSER.

ORNITHOLOGY.—*A new honey-eater from the Marianne Islands.* ALEXANDER WERMORE. Proc. Biol. Soc. Wash. **30:** 117–118. 1917.

The form of *Myzomela rubratra* (Lesson), from the island of Guam in the Marianne group, is found to be subspecifically different from *Myzomela rubratra rubratra* of the Caroline Islands, and is here described as *Myzomela rubratra saffordi.*

HARRY C. OBERHOLSER.

ORNITHOLOGY.—*On certain secondary sexual characters in the male ruddy duck,* Erismatura jamaicensis (Gmelin). ALEXANDER WETMORE. Proc. U. S. Nat. Mus. **52:** 479–482. 1917.

This paper records the discovery of a tracheal air sac in the male ruddy duck, *Erismatura jamaicensis.* This sac and the peculiar internal structure of the larynx of this species are described. The sac is absent in the females, and functions in the males evidently as an aid in swelling out the neck in sexual display. The discovery of similar structures in other species of the subfamily Erismaturinae is forecast.

HARRY C. OBERHOLSER.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

GEOLOGICAL SOCIETY OF WASHINGTON

The 324th meeting was held in the lecture room of the Cosmos Club on January 9, 1918.

REGULAR PROGRAM

FRANK J. KATZ: *Pleistocene shore lines in Maine and New Hampshire.* Uplifted beaches and deltas in the coastal counties, Cumberland and York, Maine, and Strafford and Rockingham, New Hampshire, lie near the margins and somewhat higher than adjacent deposits of late Wisconsin marine clays. The shore structures discussed are those at maximum elevations in the several localities and constitute a correlated series rising progressively from 155 feet above sea level in Stratham, New Hampshire, to 300 feet in Pownal, Maine, and higher at points farther west and north. They indicate that the postglacially uplifted surface has been tilted 5 to 6 feet per mile in a direction 40°E. of S., and that the lines of equal elevation approximately parallel the shore of the Gulf of Maine.

M. R. CAMPBELL: *Subdivisions of the Allegheny Plateaus.* No abstract.

The 325th meeting was held in the lecture room of the Cosmos Club on February 13, 1918.

INFORMAL COMMUNICATIONS

Mr. J. NEWTON BAKER presented an appeal for the National War Savings Committee for the purchase of War Savings Stamps by members of the Society.

REGULAR PROGRAM

BERTRAM L. JOHNSON: *The Valdez delta.* The Valdez delta is the dominant member of a group of youthful confluent deltas surrounding the head of Port Valdez, Prince William Sound, Alaska. It is an advancing, steep-fronted delta formed in a rugged, mountainous country under glacial or near glacial climatic conditions, the torrential, heavily débris-laden, aggrading streams from the Valdez Glacier in summer dropping their load suddenly and within short distances in deep, quiet, oceanic waters. The subaerial portion of the delta has an

area of about 10 square miles. This portion slopes to the southwest from the foot of the Valdez Glacier at an elevation of 250 feet to tidewater, a distance of 4 miles. At the foot of the glacier the delta is 1¼ miles across. The lower edge is 4 miles in length. The submarine frontal slope of the delta is steep, ranging from 6½ to 21 degrees. It joins the subaerial portion of the delta at a sharp angle, and before the construction of the present wharves large ocean vessels could at low tide moor in deep water along the delta front and safely discharge their cargo by derrick onto dry land. The junction of this frontal slope with the gently sloping fiord floor is much less abrupt but in some places seems to be quite sharp. The thickness of the delta gravels may be estimated by constructing cross sections of the delta. The delta materials rest on a basement of metamorphic rocks. Intense glacial erosion has impressed on this bedrock a characteristic topography markedly different from the constructional topography of the delta. By a comparison of the delta profiles crossing the junction of these two types of topography it is possible to locate approximately the base of the delta gravels and to determine the thickness of the delta deposits as probably a little over 300 feet.

R. S. Bassler: *Paleozoic rocks and fossils on the Piedmont of Maryland.* The western part of the Piedmont plateau in Maryland and Virginia contains areas of early Paleozoic limestone infolded in the pre-Cambrian crystallines and overlain in part by the Triassic (Newark) series. These limestones outcrop at one point next to the early Cambrian Harpers shale, and hitherto it has been believed that they represented the Shenandoah limestones of the Appalachian Valley, comprising strata from early Cambrian to Middle Ordovician time. Detailed mapping of this area and the discovery of fossils have shown that this Piedmont limestone consists of a lower massive limestone division containing Lower Beekmantown fossils and an upper thin-bedded dark blue limestone with a Chazyan fauna, the two separated by a well-marked disconformity. The Lower Beekmantown division can be correlated directly with strata in the Appalachian Valley but the Chazyan portion has no representative there.

O. E. Meinzer: *The glacial history of Columbia River in the Big Bend region.* In the Glacial epoch a lobe of the ice sheet was pushed down the valley of Okanogan River, in north-central Washington, and across Columbia River, diverting the waters of the Columbia over the upland of central Washington. In its new course the river cut precipitous gorges several hundred feet deep, developed three cataracts, at least one of which was larger than Niagara, formed a large lake in Quincy Valley, and performed an almost incredible amount of work in carrying boulders many miles and gouging out holes as much as 200 feet deep. The upper part of this abandoned channel of the Columbia has been described by T. W. Symons, I. C. Russell, and F. C. Calkins. Both Symons and Russell made vague references to a very large Pleistocene Lake, which Symons called Lake Lewis. In the fall of 1916, A. T. Schwennesen made an investigation of the water resources of Quincy Valley (see

U. S. Geol. Survey Water-Supply Paper 425), and most of the present paper is based on an automobile reconnaissance that the writer made with him in the region through which the abandoned channel passes.

The region is underlain, for the most part, by Yakima basalt. Where the diverted waters reached the monoclinal fold in the basalt that causes the descent into Quincy Valley they apparently formed a cataract, which retreated about 17 miles, cutting through the basalt a gorge several hundred feet deep. The ancient falls resemble Niagara Falls in consisting of two parts separated by an island corresponding to Goat Island. A short distance down stream there is a similar island past which the falls had retreated a little earlier in their history. The ancient falls, which may be called "Grand Falls," as they occur in Grand Coulee, were somewhat wider and higher than Niagara Falls. As an agent of erosion, the Pleistocene Columbia had two great advantages over the present Niagara: (1) It fluctuated much more and in heavy floods probably carried at least three times as much water as the maximum of the modern Niagara. (2) It was much better provided with tools for erosion than the Niagara, as is impressively shown by the great quantity of large boulders in the glacial outwash below the mouth of the gorge. Although the basalt through which Grand Falls retreated was more difficult to excavate than the rocks through which Niagara Falls are retreating, less time was probably required to make this retreat of 17 miles than for Niagara Falls to make its retreat of only 7 miles. At the mouth of the gorge the ancient river discharged, in the early part of its history, into a lake which occupied Quincy Valley, as is indicated by the topography, by fossiliferous stratified deposits, by erratic glacial boulders of granite and quartzite which must have been carried to their present positions by icebergs, and by two ancient water falls along the present gorge of Columbia River obviously caused by the overflow of the lake.

An interesting story of postglacial erosion and deformation is told by the well-developed terraces of the Columbia, which are related in various ways to the glacial features.

The 326th meeting was held in the lecture room of the Cosmos Club on March 13, 1918.

REGULAR PROGRAM

KIRK BRYAN: *Classification of springs.* (Illustrated.) No abstract.

ARTHUR J. COLLIER: *A formation hitherto unaccounted for in North Dakota.* (Illustrated.) In the collection of photographs made by A. L. Beekly in the Culbertson lignite field, there are several very good views of filled valleys in which the filling is being eroded by the present streams which flow through them in narrow canyons or gullies. No statement of the materials or agents filling these valleys is given, and one is left to infer that it is alluvium deposited at some old level of Missouri River.

Filled valleys of this character are rather common features along the Missouri in both eastern Montana and western North Dakota. The material filling the valleys is uniformly fine-grained like much of the alluvium of the present flood plain. It is generally unstratified but in places contains thin layers of débris from the Fort Union formation, which crops out higher up on the valley sides. Where cut by the streams it stands out in nearly vertical light-colored cliffs from a few feet to 30 feet in height, having a tendency to break with vertical joints from top to bottom. That it is not ordinary alluvium is proved by the fact that its surface consists of long even slopes from the valley sides and not of level plains. The material is as unstratified as glacial till, but unlike till it does not contain angular fragments of granite, and in several places it was found resting on glacial till. That the valley fillings are of comparatively recent age is shown by the fact that from one of them the head of a mountain sheep that became extinct in this neighborhood only a few years ago was found at an elevation of 150 feet above the river. While the writer was camped near the Missouri in North Dakota several severe wind storms occurred. The river was low and exposed a great many expanses of sun-dried mud, and the winds gathered up great quantities of dust and carried it high in the air. After a day of such wind the tent floors showed a very perceptible coating of dust. Some of this dust undoubtedly had been carried for long distances and was deposited wherever there was a lodgment free from wind. In the winds there is an agent of deposition which is not accounted for, and the writer believes that such winds are responsible for valley fillings of this character; in other words, that these valleys are filled with loess. If this conclusion is correct, it is probable that a large part of the rich soil of North Dakota and Montana was brought in and is constantly replenished by the wind.

GEORGE L. HARRINGTON: *Late Tertiary and Quaternary history of the lower Yukon River region.* (Illustrated.) In the lower Yukon Valley there appears to be no dividing line between the late Tertiary and the Quaternary. No fossils have been found in the unconsolidated silts, sands, and gravels, and interpretations of the geologic history are based on the unconsolidated deposits, high terraces along the river, and horizontal lava flows.

The events of the late Tertiary and Quaternary in this region include subsidence of the land surface, extrusion of basaltic lavas, further subsidence, reelevation, adjustments of drainage in the silt-filled valleys, and erosion by the processes normal to subarctic and arctic regions.

ESPER S. LARSEN, *Secretary.*

BIOLOGICAL SOCIETY OF WASHINGTON

The 585th regular meeting of the Society was held in the Meeting House of the Friend's School, 1809 I Street N.W., Saturday, May 4, 1918; called to order at 8 p.m. by President ROSE; 26 persons present.

The President announced that the sixth lecture of the Washington Academy of Sciences on science in relation to the war would be given by Dr. Raymond Pearl, on "Biology and War," Thursday, May 9, 1918.

Under the heading of brief notes and exhibition of specimens Dr. PAUL BARTSCH called attention to the destruction by fire of one of the handsomest rhododendron thickets in the District flora and to the breeding of starlings in a deserted woodpecker's hole in one of the trees of the Howard University grounds, the hole having been lately occupied by a redheaded woodpecker. He also called attention to the habit of a terrestrial spider in covering the opening of its burrow with a leaf during rains.

Mr. ALEX. WETMORE exhibited a fragment of a *Puffinus* bone obtained from Calvert Cliffs, Chesapeake Beach, Maryland.

The regular program was as follows:

MARTHA BREWER LYON; *Fauna of the human eye.* Dr. Lyon had made a careful examination of the literature as indexed in the Surgeon General's Library and the Index Medicus which reveals the following animals occuring in the human eye and its adnexa, the figures after the names indicating the frequency of their occurrence: *Treponema pallidum* infinite; *Taenia solium*, between 300 and 400; *Taenia echinococcus*, 75 to 100; *Opisthorchis felineus*, 1; *Paragonimus ringeri*, 1; *Agamodistoma ophthalmobium*, 1; *Monostomulum lentis*, 1; *Drancunculus medinensis*, 3; *Loa loa*, 30 to 50; *Agamofilaria oculi*, 3; *Filaria equina*, 2; *Filaria conjunctiva*, 3; *Thelazia callipaeda*, 2; *Trichinella spiralis*, 2; *Lepeophtheirus, pectoralis*, 1; *Demodex folliculorum*, 8; *Ixodes ricinus*, 1; *Pediculus capitis*, no cases reported though seen by many ophthalmologists; *Phthirius pubis*, 30 to 50; among the diptera, all larval form, many unidentified, those identified or at least named, *Hypoderma bovis*, 2; *Oestrus ovinus*, 2; *Gastrophilus haemorrhoidalis*, 2; *Musca domestica*, 2; *Wohlfartia magnifica*, 2; *Lucillia macellaria*, 1; *Calliphora vomitoria*, 1; *Sarcophaga* sp., 1; beetle larvae, *Necrobia* sp., 1. The fly larvae are mainly represented by forms which deposit living larvae.

Dr. Lyon touched on the early history, geographic distribution, location in the eye, means of diagnosis, description of parasite, symptoms, and in some cases the probable outcome with treatment. Some interesting observations were brought out as the prevalence of cysticercus cellulosae in Germany before the inspection of pork by the state and its practical elimination since; the many reported cases of pubic lice on the eyelashes of children against very few reported for head lice; the possibilities of the future study of the cause of chalazia by *Demodex folliculorum*. The paper was illustrated by lantern slides. It was discussed by Drs. L. O. HOWARD and PAUL BARTSCH, and by the chair.

MAYNARD M. METCALF: *Opalina and the origin of the Ciliata.* This will appear in a future number of the JOURNAL.

M. W. LYON, JR., *Recording Secretary.*

SCIENTIFIC NOTES AND NEWS

The Office of Public Roads and Rural Engineering, Department of Agriculture, began in May the publication of a monthly 48-page illustrated periodical entitled *Public Roads*.

The Biological Society of Washington has just published, as its Bulletin No. 1, *A sketch of the natural history of the District of Columbia, together with an indexed edition of the U. S. Geological Survey's 1917 map of Washington and vicinity*.[1] The author and editor is Mr. W. L. McAtee, Corresponding Secretary of the Society. The book contains historical sketches, with bibliographies, of the development of various branches of natural science in the District, including the botany, insects, other invertebrates, fishes, batrachians and reptiles, birds, mammals, and records of early man; also three chapters on the distribution of life in the District of Columbia region. A thorough index to the 1917 map of Washington and vicinity, together with a quartered and index-ruled copy of the map, is included.

Dr. Charles W. Burrows, associate physicist at the Bureau of Standards and in charge of the Magnetic Section of the Bureau, has presented his resignation to be in effect July 1, 1918, and will take up commercial research and consultation work in New York. He will have laboratories equipped for research on magnetic materials at Grasmere, Borough of Richmond, New York City.

Professor E. C. Franklin, of Stanford University, California, was in Washington in May in connection with the war work of the Bureau of Mines.

Mr. Walter M. Gilbert has resigned as assistant secretary of the National Research Council, and is now attached to the office of the Secretary of War.

Colonel Henry S. Graves, Chief of the Forest Service, has been elected an honorary member of the Royal Scottish Arboricultural Society of Edinburgh, in recognition of his eminent services to forestry.

[1] Biological Society of Washington, Biological Survey, Department of Agriculture; price $2.00, or $2.15 post-paid.

Professor H. R. MOODY, of tne College of the City of New York, Professor SAMUEL A. TUCKER, of Columbia University, and Dr. E. R. WEIDLEIN, associate director of the Mellon Institute of Pittsburgh, are members of the consulting staff of the chemicals and explosives section, War Industries Board, Council of National Defense. According to the *Official Bulletin*, the consulting staff has jurisdiction over questions involving inorganic chemicals, electrolysis, electrometallurgy, ceramics and refractories, organic compounds, and dyestuffs.

Professor ARTHUR A. NOYES, of the Masschusetts Institute of Technology, has been in Washington since May as chairman of the committee on nitrate investigations of the National Research Council, advisory to the Nitrate Division, Ordnance Department. The other members of the committee are Lieutenant-Colonel ALFRED H. WHITE, formerly professor of chemical engineering at the University of Michigan, and Dr. JOHN JOHNSTON, executive secretary of the National Research Council.

Professor MILES S. SHERRILL, of the department of physical chemistry, Massachusetts Institute of Technology, is in Washington for the summer, and is engaged in work for the Nitrate Division of the Ordnance Department of the Army.

Mr. J. B. TUTTLE resigned from the Bureau of Standards on April 15, 1918, and is with the Firestone Tire and Rubber Company of Akron, Ohio.

Captain F. E. WRIGHT has been detailed as Army representative in the section of optical glass and instruments of the War Industries Board, Council of National Defense.

The following persons have become members of the ACADEMY since the last issue of the JOURNAL:

Mr. ALBERT VICTOR BLEININGER, Bureau of Standards, 40th and Butler Streets, Pittsburgh, Pennsylvania.

Dr. WILLIAM WALLACE CAMPBELL, Lick Observatory, University of California, Mt. Hamilton, California.

Dr. CHARLES THOM, Microbiological Laboratory, Bureau of Chemistry, Department of Agriculture, Washington, D. C.

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